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(71) Applicant: KONINKLIJKE PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(72) Inventors: DE HAAN, Gerard; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). KLOMPENHOUWER, Michiel, A.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(74) Agent: GRAVENDEEL, Cornelis; Internationaal Octrooibureau B.V., Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

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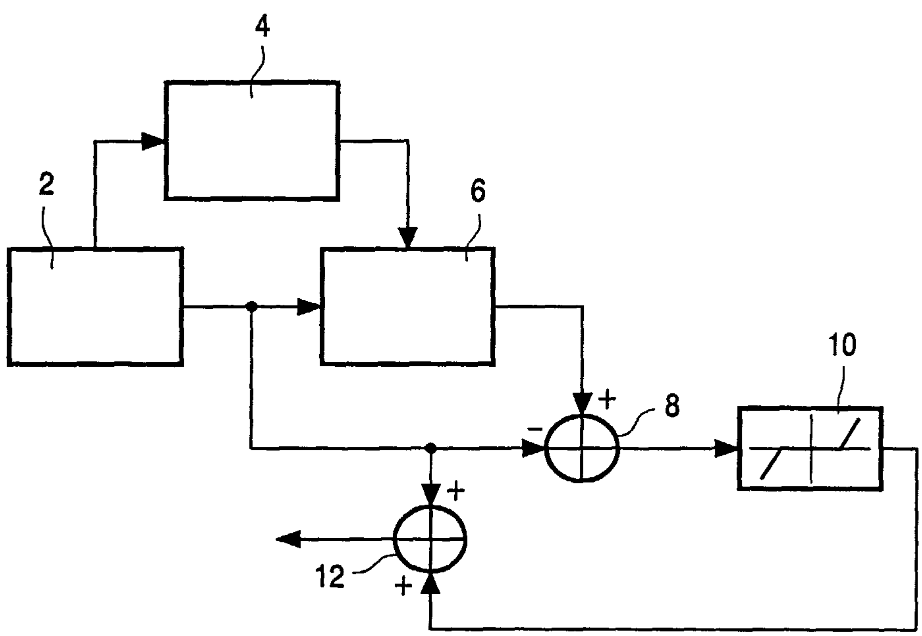
(54) Title: ANTI MOTION BLUR DISPLAY




(57) Abstract: The invention relates to a method, a circuit arrangement and a display device which suppresses motion blur due to motion integration carried out along a motion trajectory on the image data . As in matrix type displays a motion trajectory is integrated by the viewer and/or the display, an inverse integration filtering of the video signal is carried out. To avoid de-blurring in image regions where not motion can be detected, or image detail is low and to avoid noise modulation, motion estimation as well as further image characteristics are used.

WO 02/104005 A1

# Anti motion blur display

The invention relates to a method for reducing motion blur of images shown in display devices, in particular resulting from integration by the viewer of pixel intensities along the motion trajectory which can be interpreted as a low-pass filtering in the spatial domain, due to motion dependant spatial low pass filtering on image data along a motion trajectory, in which motion vectors depending on moving components of an input video signal are calculated, in which filter coefficients depending on said motion vectors are calculated, in which said input video signal is filtered depending on said filter coefficients providing a filtered video signal, in which an output video signal is generated by combining said input video signal and said filtered video signal, and in which images are generated on said display device depending on said output video signal. The invention further relates to a circuit arrangement providing anti motion blur function and a non stroboscopic display device. Said motion dependant spatial low pass filtering might as well be caused by the display itself.

The invention provides a favourable dynamic behaviour of non-stroboscopic display devices such as Liquid Crystal Displays, Plasma Panel Display or Colour Sequential Displays.

From EP 0 657 860 A2 it is known that motion blur in non-stroboscopic displays can be reduced by filtering an input video signal. The filtering is carried out as a speed dependant high spatial frequency enhancement. As the viewer of moving objects on a matrix display integrates the intensity of the pixels along the motion trajectory, which corresponds to a low pass filtering in the spatial frequency domain, motion blur may be reduced by filtering the high spatial frequency of moving objects. According to this document, matrix video display systems for displaying moving images comprise a matrix display panel having a row and column array of picture elements for producing display outputs, and a picture element drive circuit for driving the picture elements according to a video signal applied to an input by addressing the rows of picture elements in sequence repetitively in successive fields, with the picture elements holding their display outputs for at

least a substantial part of the interval between successive addressing. These matrix display devices are non-stroboscopic displays. To reduce motion blur, it is proposed that a speed dependant high spatial frequency enhancement filter circuit is provided, via which video information of a video signal applied to said input is supplied to the picture element drive circuit and which enhances the spatial frequencies of moving components in the image to be displayed according to the speed of the moving components. The higher the speed of the moving components, the larger the part of the spectrum that needs enhancement.

A drawback of the proposed solution is that in areas where the motion vector is not reliable, i.e. in areas where there is little contrast, filtering may be carried out without improving the picture. Furthermore, filtering may even cause noise modulation. In such a case flat parts of the picture are filtered where filtering cannot improve significant detail. It can, however, result in visible differences in noise patterns.

It is an object of the invention to provide an exact spatial filtering with reduced noise modulation.

To solve the object of the invention it is proposed that the enhancement filter further depends on image characteristics determining high spatial frequency properties of said video signal. By using further image properties, in particular local image characteristics, which determine high spatial frequencies, filtering in flat regions of the image, e.g. undetailed areas, can be avoided. This filtering may be carried out by second filtering means as well as enhanced first filtering means. The calculation or estimation of the motion vector may then contain slight errors. These errors might be suppressed, as the filter does use additional information regarding high spatial frequencies of the image to carry out the high spatial frequency filtering. The filtering is thus limited to regions, where it can bring advantages to the dynamic behaviour of the display.

Image characteristics according to claim 2 are further proposed. Thus the output of the filter is more reliable. By using more image characteristics, noise modulation, which is undesired, can be reduced.

A method according to claim 3 is a further preferred embodiment of the invention. As the viewer and/or the display low-pass filters the images, it is necessary to

provide an inverse filtering to reconstruct the original signal. The high spatial frequency boosting filter provides an approximate inverse function to the low pass filtering carried out by the viewer and/or the display. The filter may be a finite impulse response (FIR) as well as an infinite impulse response (IIR) filter.

The output of a high spatial frequency boosting filter can be compared to the input video signal. Differences between these two signals depend on the estimated motion vectors, at least. In flat areas, or in areas with high contrast detail, a high spatial frequency boosting might not be wanted. To provide these features a method according to claim 4 is proposed. The masking circuit might apply a ramp function to the compared video signal. Also masking circuits suppressing low and very high output values are possible. Suppressing the frequency boosting should be carried out in the event of high contrast detail. Such boosting would otherwise lead to clipping or the dynamic range of the signal would need to be decreased to prevent such peaking at the cost of average brightness of the screen.

A threshold filter according to claim 5 is a further preferred embodiment. By using threshold values, differences between the input video signal and the filtered video signal caused by imprecise motion vectors occurring in flat areas of the picture are not boosted. Only output signals of the high spatial frequency boosting filter above a defined threshold value are not suppressed.

A further aspect of the invention is a circuit arrangement for providing motion blur suppression to video displays, in particular with a previously described method, comprising motion calculating means for calculating motion vectors in a video signal, means for calculating filter coefficients depending on said motion vectors, first filtering means for filtering said video signal depending on said filter coefficients, and means for adding said filtered video signal to said input video signal, characterised in that second filtering means for filtering said video signal depending on image characteristics determining high spatial frequency properties of said video signal are provided. Said second filtering means may be comprised in said first filtering means as an enhancement of the first filtering means. Also said second filtering means may be provided by an independent new filtering circuit.

Yet a further aspect of the invention is a non-stroboscopic display device, in particular a Liquid Crystal Display (LCD), a Thin Film Transistor Display (TFT), Colour

Sequential Display, or a Plasma Display Panel (PDP) comprising a previously described circuit arrangement according to claim, or with a previously described method.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter. In the figures show:

Fig. 1 a first embodiment of an anti motion blur filter;
Fig. 2 a second embodiment of an anti motion blur filter.

In cathode ray tubes, each pixel of a displayed image is generated as a pulse, which is very short compared to the picture time. Different to cathode ray tubes, in new flat, high quality, low cost displays devices, each pixel is displayed during most of the picture time. In case any part of the picture contains motion, the viewer will track this motion. As each pixel is displayed substantially the whole picture time, the intensity of pixels showing the motion is integrated along the motion trajectory as follows:

$$F_{out}\left(\vec{x}, n\right) = \frac{1}{t_i}\int_0^{t_i} F\left(\vec{x} + \frac{t}{T}\vec{D}, n\right)dt \qquad (1)$$

with $t_i$ as display time, F as input video signal, $F_{out}$ as output video signal, and T as picture period. The vector D is the product of the object velocity and the picture period. In case $t_i$ is constant, the integration is the same as a convolution of F(x,n) and a sample-and-hold function h(x):

$$\begin{aligned} F_{out}\left(\vec{x}, n\right) &= \frac{T}{t_i}\int_0^{\frac{t_i}{T}} F\left(\vec{x} + \alpha\,\vec{D}, n\right)d\alpha \\ &= \int_{-\infty}^{\infty} F\left(\vec{x} + \alpha\,\vec{D}, n\right)h_1\left(\alpha\,\vec{D}\right)d\alpha \qquad (2) \\ &= F\left(\vec{x}, n\right) * h\left(\vec{x}\right) \end{aligned}$$

where h(x) is

$$h_1(\alpha\vec{D}) = \begin{cases} T/t_i, & 0 \le \alpha \le T/t_i \\ 0, & otherwise \end{cases} \qquad (3)$$

From an analysis in the Fourier domain, it is apparent that the original signal can be reconstructed by inverse filtering the output signal:

$$F(\vec{f},n) = \frac{F_{out}(\vec{f},n)}{H(\vec{f})} = \frac{F_{out}(\vec{f},n)}{\sin c\left(\pi \frac{t_i}{T} \vec{D} \cdot \vec{f}\right)} \qquad (4)$$

As the transfer function H(f) contains zeros, this inverse filtering is not practicable. In practise a modified filter is required. Such a filter boosting high spatial frequencies with a similar behaviour as the sinc function is:

$$F_{out1}(\vec{x},n) = F(\vec{x},n) + G(\vec{D}) \sum_{k,l,n} C(\vec{D},l,k) F\left(\vec{x} + \begin{pmatrix} k \\ l \end{pmatrix}, n\right) \qquad (5)$$

with the second term of the equation being a high pass finite impulse response filter, which coefficients depend on the motion vector D.

As this boosting of high spatial frequencies contains the risk that variations of the filter in areas where the motion vector D is unreliable become visible as a modulation of the noise, these unreliable vectors have to be eliminated or suppressed.

Figure 1 depicts a diagrammatic circuit arrangement which allows to reduce motion blur and noise modulation. In figure 1 video signal input source 2, a motion estimator circuit 4, an high spatial frequency boosting filter 6, a comparator 8, a masking circuit 10 and an adder 12 are depicted.

A video signal from said video signal input source 2 is fed to said motion estimator circuit 4. In said motion estimator circuit 4, motions in the images of the video signal are estimated and filter coefficients are calculated depending on the estimated motion vectors. The higher the motion in an image, the bigger the motion vectors. The filter

coefficients are fed to said high spatial frequency boosting filter 6, which may be an IIR or an FIR filter as depicted in the equation (5) above.

By filtering said video signal according to said filter coefficients, high spatial frequencies are boosted. The output signal of said high spatial frequency boosting filter 6, where high spatial frequencies are peaked and low spatial frequencies are constant, is fed to said comparator 8. By said comparator 8, the differences between the input video signal and the boosted video signal are calculated and output. Thus, only in case said high spatial frequency boosting filter 6 has changed said input video signal, said comparator 8 has an output.

In flat areas, where most motion estimation circuits have difficulties in finding a valid motion vector, the filter coefficients and thus the output of said high spatial frequency boosting filter 6 are not reliable. Areas where the output of said motion estimator circuit 4 is not reliable, the output of said high spatial frequency boosting filter 6, and in the following the output of said comparator 8, have low amplitudes. To suppress these low amplitudes, said masking circuit 10 provides masking functionality to the filter. It is also possible to mask high amplitude high frequencies, as these frequencies derive from high contrast detail areas of the picture. If these high amplitude frequencies would be peaked by said high spatial frequency boosting filter 6, the overall dynamic range of the display would have to be decreased at the cost of average brightness of the picture, otherwise clipping would occur. A masked signal is fed to said adder 12, where it is added to said input video signal. The output signal is:

$$F_{out2}(\vec{x},n)=\begin{cases} F(\vec{x},n) & ,(|F_{out1}(\vec{x},n)-F(\vec{x},n)|)\leq Th \\ F_{out1}(x,n)+Th & ,(F_{out1}(\vec{x},n)-F(\vec{x},n))<-Th \\ F_{out1}(x,n)+Th & ,(F_{out1}(\vec{x},n)-F(\vec{x},n))>+Th \end{cases} \tag{6}$$

where Th is a threshold value that prevents boosting in low contrast areas, e.g. in areas where the filter coefficients are not reliable.

A further preferred embodiment of the invention is depicted in figure 2. In addition to figure 1, in figure 2 a peak to peak calculator 14, a mean signal value calculator 16, and a lookup table 18 are depicted. In particular in Plasma Display Panels, this

embodiment is preferred, but is not restricted to this display type. As the main motion blurring is caused by the most significant bit or pixel that varies due to the image detail, this information can be used in combination to the estimated motion vector to determine the filter coefficients for said high spatial frequency boosting filter 6.

Besides the motion estimation carried out by motion estimator 4, a peak to peak value of a high frequent video component of the input video signal is calculated by said peak to peak calculator 14. In addition, the mean signal value is calculated by said mean signal value calculator 16. These values, in addition to the motion vector, are used to calculate filter coefficients for said high spatial frequency boosting filter 6. The calculated filter coefficients are stored in said lookup table 18 and can be read by said high spatial frequency boosting filter 6.

The invention allows to remedy motion blur occurring in matrix-type displays. As motion vectors are not always reliable, further image characteristics are used to overcome the uncertainty of motion vector estimation. Thus, noise modulation in flat image areas can be avoided, and de-blurring is only carried out in image regions where it makes sense. Otherwise de-blurring is suppressed.

CLAIMS:

1. Method for reducing motion blur of images shown in display devices, in particular resulting from integration by the viewer of pixel intensities along the motion trajectory which can be interpreted as a low-pass filtering in the spatial domain, due to motion dependant spatial low pass filtering of image data along a motion trajectory, in which motion vectors depending on moving components of an input video signal are calculated,

in which filter coefficients depending on said motion vectors are calculated,

in which said input video signal is filtered depending on said filter coefficients providing a filtered video signal,

in which an output video signal is generated by combining said input video signal and said filtered video signal, and

in which images are generated on said display device depending on said output video signal,

characterised in that said input video signal is further filtered depending on image characteristics determining high spatial frequency properties of said video signal.

2. Method according to claim 1, characterised in that said image characteristics are image detail, and/or image contrast, and/or image texture, and/or a mean signal value, and/or a peak to peak value.

3. Method according to claim 1, characterised in that said input video signal is filtered by means of a high spatial frequency boosting filter depending on said filter coefficients

4. Method according to claim 1, characterised in that said input video signal is compared to said filtered video signal, that said compared video signal is filtered by a masking circuit, and that said output video signal is generated by combining said input video signal and said masked video signal.

5. Method according to claim 4, characterised in that said masking circuit provides a threshold masking to said compared video signal, that below said threshold said compared video signal is substantially suppressed, and that above said threshold said compared video signal is at least partially boosted.

6. Circuit arrangement for providing motion blur suppression to video displays, comprising motion calculating means for calculating motion vectors in a video signal, means for calculating filter coefficients depending on said motion vectors, first filtering means for filtering said video signal depending on said filter coefficients, and means for adding said filtered video signal to said input video signal,

characterised in that second filtering means for filtering said video signal depending on image characteristics determining high spatial frequency properties of said video signal are provided.

7. Non-stroboscopic display device, in particular a Liquid Crystal Display (LCD), a Thin Film Transistor Display (TFT), Colour Sequential Display, or a Plasma Display Panel (PDP) comprising a circuit arrangement according to claim 6, or operated with a method according to claim 1 to 5.

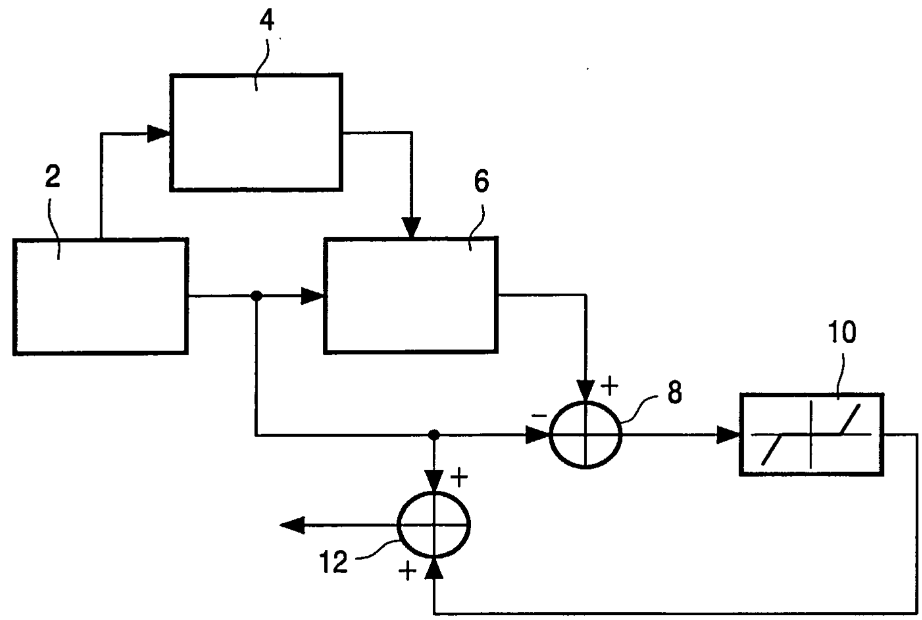



FIG. 1

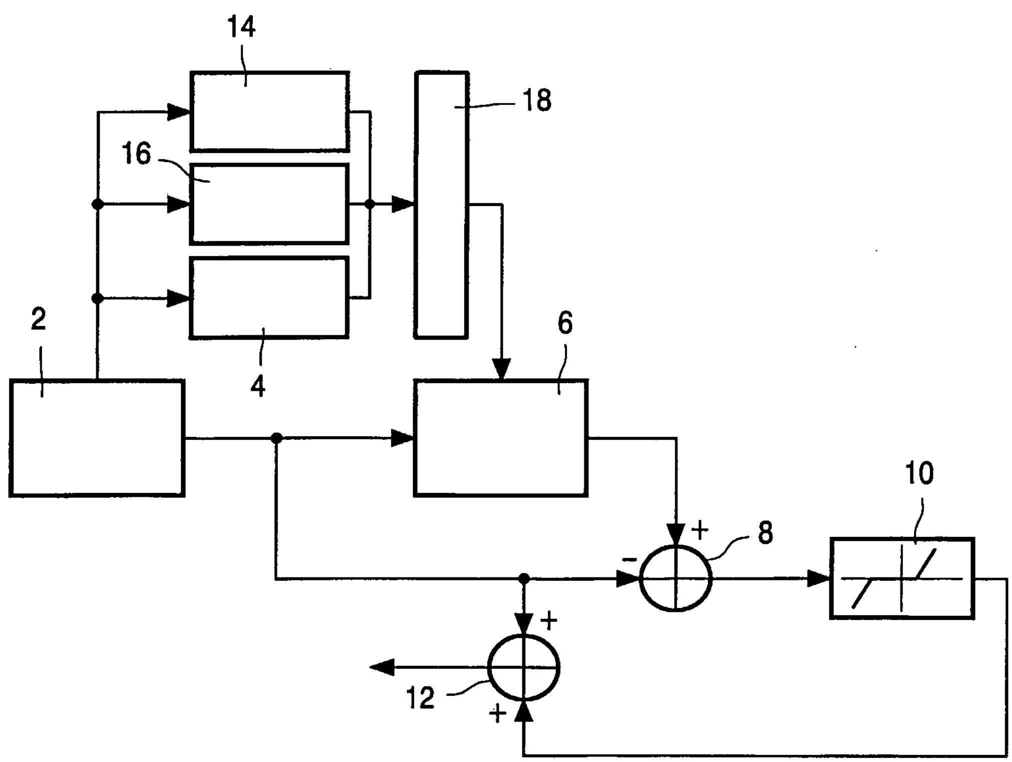



FIG. 2

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 02/02213

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 H04N5/208 H04N5/21

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 17 September 2002 | 24/09/2002 |

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